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RE-ORIENTATABLE SAMPLE HOLDER

This invention relates to a reorientable sample holder
whose location and orientation can be determined. For

5   example, it may be used for the scanning of samples in
two stages and matching together the data from the two
stages providing coherent information. A preferred form
relates to the scanning of dentalware such as
frameworks for dentures.

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One way that three-dimensional samples are scanned
involves a stationary sample, a probe having three
dimensional movement and styli that can access the
whole surface of the sample including the underside

15   enabling the whole surface to be scanned.

A problem with this method is that the equipment used
requires a relatively large working space so it is
unsuitable for situations where there are size

20   limitations. A solution to this problem is to rotate
the sample during the scanning process as this reduces
the number of degrees of freedom that the probe
requires. However, this solution results in further
problems when scanning samples which have undercuts as

25   this can lead to incomplete scans. Different problems
are encountered when elongate samples, such as dental
bridges, are involved.

The present invention provides a device comprising:

30   a base; and
        a re-orientatable sample holder adapted on at
least first and second sides to be repeatably mounted
on the base characterised in that the relationship
between the at least two surfaces when mounted on the

base is known whereby when a sample is mounted to the re-orientatable sample holder, the relationship between the different orientations of the sample when different surfaces of the re-orientatable sample holder are
5 received on the base is known.

The surfaces of the re-orientatable sample holder which are adapted to be repeatably mounted on the base have a unique relationship to each other which can be
10 mathematically defined. Thus, the sample holder can be re-orientated without losing the location of a first surface with respect to the base, and a sample located thereon. One way to mathematically define this relationship is by using reference features.
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The relationship between the at least two surfaces of the re-orientatable sample holder is established by a plurality of reference features on the re-orientatable sample holder which provide positional information
20 about the re-orientatable sample holder when received on a base. Positional information includes one or more of translational and rotational information.

Reference features may be provided by one of a number
25 of methods including the provision of a reference block of material of known dimensions and having machined faces which adjoins or forms part of the re-orientatable sample holder. Alternatively three spheres or rods may be provided which protrude from the re-
30 orientatable sample holder and are accessible regardless of which surface of the re-orientatable sample holder is received on the base. Other references may be taken from the sample holder itself.

In a preferred embodiment, the reference features are provided by surfaces which are commensurately larger than a device used to locate the surfaces in space (a probe or laser spot, for example) whereas the sample

5   holder must be of sufficient size to hold and/or support a sample. If the reference features are on such a block of material, machining costs are reduced. This is because the sample holder does not have to be machined to the same degree of precision as it would

10   have been to provide the reference features.

In a preferred embodiment, the re-orientatable sample holder is kinematically or quasi-kinematically received on the base by a kinematic mount. This ensures that

15   when the sample holder is re-orientated, the position of an attached sample with respect to the new orientation will either be known (if the reference features have been datumed for that sample holder on that base previously) or can be determined using the

20   reference features.

According to a second aspect of the present invention, there is provided a device enabling operation on a sample in at least two stages comprising:

25   a base;

a re-orientatable sample holder adapted on at least first and second sides to be repeatably mounted on the base; and

an operating system for operating on the sample

30   when the at least first and second sides of the re-orientatable sample holder are repeatably mounted on the base;

characterised in that the relationship between the at least first and second sides of the re-orientatable

sample holder when mounted on the base is known
enabling the at least two stages of an operation to be
joined or matched.

5   Preferably, the relationship between the at least first
and second sides of the re-orientatable sample holder
is established by a plurality of reference features on
the re-orientatable sample holder which provide
positional information about the re-orientatable sample
10   holder when received on the base.

According to a third aspect of the present invention
there is provided a method of operating on a sample in
at least two stages comprising:
15   providing a base;
               locating a re-orientatable sample holder on the
base the re-orientatable sample holder being adapted on
at least first and second sides to co-operate with the
base;
20   providing a plurality of reference features
capable of supplying data about the position of the re-
orientatable sample holder; and
               furnishing an operating system;
               wherein a first operation is made by the operating
25   system when the first side of the re-orientatable
sample holder co-operates with the base and a second
operation is made when the second side of the re-
orientatable sample holder co-operates with the base
and the at least two operations are matched together
30   using the data provided by the reference features.

According to a fourth aspect of the present invention
there is provided a method of operating on a sample in
at least two stages comprising the steps of:

providing a base;

providing a re-orientatable sample holder which is
adapted to be received kinematically on the base on at
least first and second sides wherein the relationship
5   between the first and second sides is known;

placing the re-orientatable sample holder on the
base on its first side;

operating on a first stage of a sample held in the
sample holder;

10   re-orientating the sample holder with respect to
the base onto its second side; and

operating on a second stage of a sample held in
the sample holder; wherein the

operations of the first and second stages of the
15   sample are matched using the relationship between the
first and second sides.

When a kinematic location is used, the reference
features for a particular pair of holder and base do
20   not need to be re-datumed or re-referenced for future
operations.

An operation includes the performance of a practical
work on a sample such as scanning a surface profile,
25   machining the sample, inspecting it or measuring it in
some other manner.

The invention will now be described by example with
reference to the accompanying drawings, in which:
30   Fig 1 shows an isometric view of a scanning
apparatus using a device according to the invention;

Fig 2 shows an isometric view of device according
to the invention;

Fig 3 shows an isometric view of a further device

according to the invention;

    Fig 4 shows an isometric view of an alternative device according to the invention;

    Figs 5 a-g show schematically the manufacture of a
5 dental coping using a device according to the invention;

    Fig 6 shows isometrically an indexable device according to the invention; and

    Figs 7a and b show plan views of re-orientatable
10 sample holders according to the invention.

Figures 1 and 2 show a device 1 having a base 2 with a support surface 3. A re-orientatable sample holder 4 is T-shaped and has three ball bearings 5,6,7 embedded in
15 both its upper surface and in its lower surface (not shown). One ball bearing is disposed near each end of the 'T' on each side. A cube 8 is adjoined to the re-orientatable sample holder 4 and has four machined faces 9,10,11,12 which provide reference features. A
20 tooth framework 13 is secured to the sample holder 4 via removable end pieces 14, 15 which are secured by screws 16,17 to each end of the top of the 'T' of the sample holder.

25 The tooth framework 13 is attached to the sample holder by at least partially removing the screws 16, 17 that hold the end pieces 14,15 to the sample holder and inserting the ends of the framework 13. When the screws 16,17 of the end pieces 14,15 are tightened, the
30 framework is held in position.

The reference features on cube 8 and the framework 13 are scanned by a contact probe 22. An alternative scanner would be a laser probe.

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Referring now to Figure 2, the support surface 3 has a
magnet 18 disposed at its centre and three v-shaped
grooves 19,20,21 lying radially spaced 90° apart (thus
forming a 'T' shape). The three ball bearings 5,6,7 in
5   each side of the re-orientatable sample holder 4 are
disposed so that one lies vertically above/below
another thus, each set of three balls co-operates with
the three v-shaped grooves 19,20,21 in the support
surface 3. This means that when the sample holder is
10   reversed with respect to the base, the sample holder
and thus the sample held therein are located in
substantially the same place.

It will be appreciated that the grooves 19,20,21 and
15   balls 5,6,7 form a (slightly degenerate) kinematic
mount. Kinematic mounts of various types are well
known, and described in (for example) HJJ Braddick,
"Mechanical Design of Laboratory Apparatus" Chapman and
Hall, London, 1960. Other kinematic mounts (and quasi-
20   kinematic or partly degenerate kinematic mounts) may be
used instead.

In order to obtain a complete scan of the surface of
the framework 13, the framework is secured to the
25   sample holder 4 as described above. The sample holder 4
is then placed on the support surface 3 in an
orientation such that each ball bearing 5,6,7 co-
operates with a groove 19,20,21. The magnet 18 ensures
that this position is maintained until the sample
30   holder 4 is removed from the base 3. Assuming this is
the first scan using this holder and base i.e. the
relationship between the two surface it not known, then
firstly reference features are pinpointed followed by a
scan of the upper portion of the framework 13. Once

this first part of the scan is complete, the sample
holder 4 is reversed with respect to the base 3.
Reference features for this second surface are
pinpointed or located this time however, the reference
5   feature for the vertical position is taken from a
different face of the reference block 8 as the sample
holder 4 is now reversed compared with its original
position. The lower portion of the framework 13 is now
scanned.

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As the sample holder is kinematically located on the
base, the four reference surfaces 9,10,11,12 need only
be referenced once in respect of that sample holder
when used with that base. Thus, the above example
15   would only apply on first use of that sample holder
with that base. The reference information could then
be stored either in writing or as a part of a scanning
programme so a user need merely know which base and
holder were being used to access the reference data (if
20   available). For ease of matching the two scanned
portions, the side of the sample holder on the base
should also be identified.

In order to obtain both positional and rotational
25   information about the sample holder, both the reference
block and sample holder are datumed. The upper surface
of the sample holder is datumed at least three times in
order to define the plane of the surface and thus
sample holder. The top surface 11 of the reference
30   block provides positional information in the Z
direction and side surfaces 9 and 10 about the X
direction. An edge (either the top of the "T" or the
parallel edge to this) of the sample holder is also
datumed at two locations to establish the end location

of the holder. This information is required for each
surface of the holder which can be received on the
base. In order to match the data from the different
part scans, the other dimension required is the depth

5   of the reference block between the two surfaces. Note
when there are more than two surfaces capable of being
received, this dimension will be different for each
pair of surfaces. The person skilled in the art will
appreciate that there are alternative ways of obtaining

10 the data needed to establish where the sample holder is
in space.

One such alternative to providing reference features in
order to match-up part scans (or other operations), is

15 to use computer software and processing to re-orient
and re-position the part scans in relation to each
other and thus enable the production of a more complete
scan.

20 The reference block 8 is accurately machined so that
each face is perpendicular to the adjacent faces. The
distance between each set of opposite faces of the
block needs to be known or measured (preferably under
the same conditions as the framework scan). The

25 references taken for each part of the scan in
conjunction with the distance between the opposite
faces of the block can then be used to match the two
stages or parts of the scan (using appropriate computer
software) adjusting said scans to take in consideration

30 differences in the height and rotation of each part
scan resulting in a complete matched scan of the
framework.

When only two parts of a scan are being matched, it is

less important to know which orientation is being
scanned at one time as there are only two different
ways that the data can be matched. When there are more
scanning stages to be matched, it is advised that the
5   orientation of the sample holder is also identified to
avoid complications and possible errors when applying
the reference data to the scanned data.

If computer software and processing is used to match-up
10   part operations rather than reference features, then
identification of the surface received on the base is
useful in order that the programme can learn how the
different part operations are likely to fit together,
reducing processing time.

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Fig 3 shows a further sample holder 30 where the sample
31 is secured to the sample holder 30 using two slots
32,33 through the thickness of the sample holder. The
sample 31 is secured at each end by glue to a threaded
20   cylinder 34. The cylinder 34 is secured with respect
to the slot by two nuts 35, one located either side of
the slot 32,33.

In this example, the kinematic locator is reversed.
25   The sample holder has three "v" shaped grooves 35 and a
matching base (not shown) would have three co-operating
balls protruding therefrom. Also, in this example the
ends of the holder adjacent to 32 and 33 could be
datumed to establish the x-direction location of the
30   sample holder when on a base.

Fig 4 shows an alternative device 40 which is a cube
having a sample holder 41 on one face and kinematic
locators 42 which are three balls radially disposed by

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120°, on each of the other faces. A base 43 has co-
operating kinematic locators 44, which are three v-
shaped grooves radially disposed by 120°.

5   In this example, the reference features are provided by
        the sample holder 41 which has a central collet 45 into
        which a sample or sample mount (for example a tube) may
        be inserted. The faces of the sample holder 41 are
        accurately machined to produce reference surfaces 46.

10   By measuring the distance from each face having a
        kinematic locator 42 to a respective reference surface
        46 and the relative positions and orientations of each
        reference surface, the relative orientation and
        position of a sample (not shown) held by the sample

15   holder 41 in each possible kinematic location 42 with
        respect to the base 43 is known or derivable. This
        enables an operation, for example scanning of a sample
        to be performed in a number of stages, perhaps required
        due to the shape of the sample, and the data obtained

20   from these different stages to be matched together to
        produce a complete (if required) scan by the
        manipulation of each scanned data set using the
        measured information.

25   If a replica of the scanned sample is required, a
        machining process could be carried out using the same
        sample holder and base enabling the machining to either
        replicate the different scanning steps or, if more
        appropriate, to follow a route developed from the

30   scanned data which provides the most efficient or least
        complicated process. A device according to the
        invention could also be used for the inspection of
        samples.

Although the device has been described as a cube, it
will be appreciated that any number of faces (two or
more) may be utilised depending on, amongst other
things, size of sample, shape of sample, complexity and
5   available working space.

Figs 5a-g show schematically the manufacture of a
dental coping. The re-orientatable holder 50 is
cylindrical in shape and has a kinematic locator 51
10   comprising three ball bearings radially spaced 120°
apart on each rim 52a,b. A base 53 has a co-operating
kinematic locator 54, three v-shaped grooves radially
spaced 120° apart and describing a circle of the same
diameter as the three ball bearings (Fig 5a).
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The re-orientatable holder 50 may thus be positioned on
the base 53 in two positions, one the reverse of the
other. For clarity, reference features have not been
shown in this drawing.
20

During the manufacture of a coping, both the internal
and external surfaces of a blank must be machined. The
external surface is produced as a replica of the
original tooth shape and the internal surface is
25   produced to fit onto an abutment which locates the
tooth within a mouth. An ability to reverse the
position of the coping during the manufacture is
therefore advantageous.

30   The blank 55 is held in position on the re-orientatable
holder 50 by a disc 56 which is in two parts and has a
central hole (formed from a semi-circular hole in each
part). The two parts of the disc 55 are attached by
screws which allow a variability in the size of a blank

54 to be accommodated. Alternatively the disc 56 may
be one piece, which has a slot and central hole to
accommodate the blank, the disc being clamped by a
screw.

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The blank 55 is positioned with respect to the disc
such that one end 57 of the blank is approximately
level with the disc (Fig 5b).

10   The disc 56 is clamped to the re-orientatable device 50
by screws. Alternatively, the disc 56 is integrally
formed as part of the re-orientatable holder which has
a slot and is ring clamped to secure the blank
centrally therein.

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Once the disc 56 and blank 55 are securely positioned
in the re-orientatable device, an internal bore 58 is
produced by machining the end 57 of the blank which is
almost level with the disc 56 (Fig 5c).

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In order to provide stability to the blank for the
second machining process, the internal bore 58 and a
region 59 defined by the re-orientatable device is
temporarily filled with a resin 60 (Fig 5d). Once the

25   resin has cured sufficiently to provide strength and
rigidity to the blank 55, the re-orientatable device 50
is reversed (Fig 5e), so the end 61 of the blank which
stands proud of the disc is available for machining.

30   The outer surface of the end 61 of the blank is
machined to produce the final shape of the coping 62
(Fig 5f). The resin is burned away leaving the coping
63 (Fig 5g). If the blank 55 is made from a ceramic
material, then the burn-off could be incorporated as

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part of the sintering process that occurs after
machining.

5   The material used to support the partially machined
blank need not be a resin but must be a removable
material which provides sufficient support for the
blank for example a wax or low melting point alloy.

10   Fig 6 shows an indexable device 70 comprising a
circular base portion 73 with a plurality of ball
bearings 74 disposed circumferentially around it. In
between each ball bearing is a gap 76 which is
approximately v-shaped. At the centre of the base
portion 73, is a magnet 77 used to urge the re-
15   orientatable device into position. A re-orientatable
device 71 is a cube having on at least two faces 72a,b
three radially spaced apart ball bearings 76 which
describe a circle having substantially the same
diameter as the plurality of ball bearings 74 in the
20   base 73. The three radially spaced ball bearings 76
are spaced 120° apart and adapted to sit in the v-
shaped gaps 75 formed between the plurality of ball
bearings 74. This provides a number of different
orientations in which the re-orientatable device may be
25   located.

Alternatively, three v-shaped grooves may be provided
thus, the re-orientatable device sits on the ball
bearings rather than within the grooves therebetween.
30   In both cases, a force is required to move the
re-orientatable device out of its current position.

If the plurality of ball bearings 74 are accurately
positioned, then the re-orientatable device 71 can be

indexed between different pairs of ball bearings
enabling precise angular movement of say 7.5 or 15°
intervals. This would enable small rotations of a
sample held in a sample holder (not shown) on a face
5   without the kinematic locators.

In addition to angular re-orientation, the
re-orientatable device 71 may be relocated onto a
different face 72b which may again be angularly
10   re-orientated enabling a great number of orientations
to be achieved.

Figs 7a and 7b show alternative embodiments of the
invention where the repeatable locator itself is used
15   to provide the initial reference or datum features used
to relate two sides of a re-orientatable sample holder
together.

The re-orientatable sample holder of Fig 7a, 80 is
20   approximately triangular in shape having a ball bearing
81 disposed at each apex. A framework 82 is mounted or
attached to one of the sides 83 of the sample holder.
The three ball bearings 81 have a diameter which is
larger than the thickness of the approximately
25   triangular-shaped central portion of the sample holder.
Thus, both sides of the sample holder may be repeatably
located (in this example kinematically located) with
respect to a base (not shown) by the provision of three
v-shaped grooves or pairs of balls to provide a seating
30   for each respective ball bearing 81. Once each ball
bearing 81 has been datumed from each side whilst
received on a particular base, and with knowledge of
the diameter of the ball bearings 81, the operation on
one side of a sample held in the sample holder can be

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related to an operation on the reverse side. The
datuming of the three balls provides the planar
information about the re-orientatable sample holder.

5   Fig 7b shows a rectangular re-orientatable sample
     holder 85 with three rods 86 protruding from three
     sides of the sample holder. The three rods lie in
     substantially the same plane. A sample holder 87 is
     attached to a fourth side and also lies in
10   approximately the same plane as the rods. A base (not
     shown) in this example requires a groove within which
     each rod can be seated which may be raised with respect
     to the base surface for example, as formed by two
     protruding balls. The base may additionally or
15   alternatively include a recess to accommodate the
     thickness of the sample holder which lies below the rod
     when seated on the base. Again, each rod must be
     datumed, when each side of the sample holder is seated
     on the base. This information along with the diameter
20   or thickness of the rod provides enough information to
     match two operations carried out on a sample with
     different sides of the sample holder seated on the
     base.